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Development of a Test for Isometric
Strength of Flattening of the Lumbar Curve
During Posterior Pelvic Tilt
in the Standing Position

By

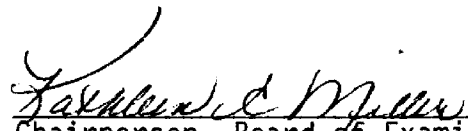
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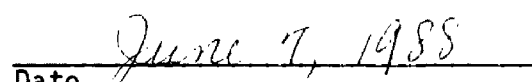
B.S., Montana State University

Presented in partial fulfillment of the requirements
for the degree of
Master of Science
University of Montana
1988

Approved by


Chairperson, Board of Examiners


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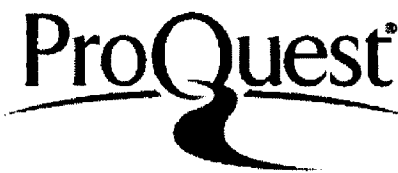


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Kirchmyer, Susan E., M.S., June 1988

Health and Physical Education

Development of a Test for Isometric Strength of Flattening of the Lumbar Curve During Posterior Pelvic Tilt in the Standing Position (53 pp.)

Director: Dr. Kathleen Miller 

This study developed a test to measure the isometric strength of flattening of the lumbar curve during posterior pelvic tilt while standing. The tests which are in general use examine flexion and extension of the upper body, involving the thorax and large muscles of the trunk. However, tests of motions which use more specific tests have been useful in pinpointing strength deficits among low back pain patients. This strength test did not involve the thorax and measured the torque exerted in a posterior direction by the lumbar area, with the thorax held stationary.

Following testing of 30 male volunteers who performed five trials, the reliability and validity of the test were investigated. Calculation of the Treatments by Subjects analysis of variance found a significant difference ($p = .0001$) among subjects. Day-to-day reliability of a subsample indicated scores were stable (Spearman Rho rank order coefficient = .80 to 1.00). Results of the intertester reliability study of a separate sample of 5 subjects, each of whom was tested by three testers, were evaluated using Kendall's coefficient of concordance ($W = .83$ to $.97$).

Validity of the test was supported by comparison of the torque values which were generated during the strength test with those reported in another test of trunk strength. In addition, the validity was supported by the data which showed that the strength scores tended to differ among subjects in accordance with their lumbar spinal mobility and with their history of low back pain. The test was concluded to be reliable and suitable for clinical use in testing persons recovering from low back problems and for research use in identifying predictive factors for low back injury.

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Table of Contents

ABSTRACT.....	ii
ACKNOWLEDGMENTS.....	iii
LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
INTRODUCTION.....	1
Statement of the Problem.....	5
Delimitations.....	6
Limitations.....	6
Assumption.....	6
METHODOLOGY.....	7
Subjects.....	7
Testing Procedure.....	7
Pilot Study Format.....	13
Back Strength Test Study Format.....	14
Statistical Treatment of Data.....	15
RESULTS AND DISCUSSION.....	17
Pilot Study.....	17
Main Back Strength Test (BST) Study.....	20
Day-to-Day Reliability Study.....	26
Intertester Reliability Study.....	27
Evaluation of Criterion Scores.....	28
Evaluation of Clinical Usefulness.....	30
Criterion Validity.....	31
Construct Validity.....	33
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS.....	39
Summary.....	39
Conclusions.....	40
Recommendations.....	40
APPENDICES.....	42
A. Informed Consent.....	42
B. Standardization of Position Angle.....	43
C. Standardized Instructions to Subjects.....	44
D. Retest Protocol.....	45

E.	Table E-1.	Pilot Study Individual Data.....	47
	Table E-2.	Main Back Strength Test Study (Same-Day, Same-Tester Study) Individual Data....	48
	Table E-3.	Day-to-Day Reliability Study Individual Data.....	49
	Table E-4.	Intertester Reliability Study Individual Data....	50
REFERENCES.....			51

List of Tables

1. Pilot Study Mean, Standard Deviation, and Range of Scores (ft-lb) of Ten Trials.....	17
2. Pilot Study Treatment by Subjects Analysis of Variance.....	19
3. Pearson Coefficients of Correlation (r) of Physical and Apparatus Factors with Mean Back Strength Test Scores.....	22
4. Back Strength Test Same-Day, Same-Tester Treatments by Subjects Analysis of Variance.....	24
5. Back Strength Test Mean, Standard Deviation, and Range for Five Trials During Same-Day, Same-Tester Study.....	24
6. Change in the Scores of Individuals Under Same-Day, Same-Tester; Day-to-Day; and Intertester Conditions.....	28
7. Range of Change and Reliability Coefficients of Criterion Scores of Individuals for Day-to-Day and Intertester Conditions.....	29
8. Mean Back Strength Test (BST) Scores of Subjects According to Modified Schober Test Scores and Deviation from Predicted Modified Schober Scores.....	33
9. Mean Back Strength Test Scores of Subjects According to History of Character of Low Back Pain.....	35
10. Mean Back Strength Test Scores of Subjects According to History of Site of Low Back Pain.....	37

List of Figures

1. Effect of Thoracic Involvement on the Direction of Torque and on the Type of Intervertebral Joint Motion During Lumbar Flexion and Extension.....3
2. Positioning of the Subject, Fulcrum and Lever Arm of Apparatus, Support Dowels, and Bracing Belts.....10
3. Deflection Angle in Relation to the Vertical and to Anatomical Sites.....12
4. Pilot Study Scores on Ten Trials by Four Subjects.....18

Introduction

The development of a test of isometric strength of flattening of the lumbar curve during posterior pelvic tilt while standing involved measuring the ability of the low back to exert torque in a posterior direction. This ability is an important aspect of lumbar stability because the low back encounters many forces in an anterior direction which must be neutralized. For example, forward moments are encountered when weight is lifted (Ekholm, Arborelius, & Nemeth, 1982; Marras, King, & Joynt, 1984). Stabilization of the lumbar spine has been seen as a crucial component of lifting (Davis, Troup, & Burnard, 1965; Grieve, 1974).



The torque exerted during flexion and extension of the lumbar spine has been widely tested. Tests have been directed toward identifying weaknesses which may lead to injury (Biering-Sorensen, 1984; Chaffin, Herrin, & Keyserling, 1978) and toward identifying strength deficits among back pain patients (Addison & Schultz, 1980; Hasue, Fujiwara, & Kikuchi, 1980; Hemborg, Moritz, Hamberg, Holmstrom, Lowing, & Akesson, 1985; McNeill, Warwick, Andersson, & Schultz, 1980; Nachemson & Lindh, 1969; Nicolaisen & Jorgensen, 1985; Thorstensson & Arvidson, 1982).

Tests in general use have examined flexion and extension of the upper body, involving the thorax and recruiting large muscles of the trunk. However, tests of motions that used a variety of pivot points were useful in locating differences in strength between low back pain patients and healthy subjects (Thorstensson & Arvidson, 1982).

Analysis of the direction of the intervertebral joint motion and of the direction of torque shows that the test of flattening of the lumbar curve during posterior pelvic tilt while standing differs from both tests of flexion and of extension which involve the thorax. Although the intervertebral joint motion is that of lumbar flexion, it differs from flexion tests which involve the thorax because pelvic tilt does not affect the thorax (Day, Smidt, & Lehmann, 1984). As a result, it measures torque exerted in a posterior direction during flexion of the spine, while other flexion tests measure torque exerted in an anterior direction. It differs from tests of spinal extension which involve the thorax, because, although both measure torque exerted in a posterior direction, the intervertebral joint motion is opposite (see Figure 1).

Several studies have shown the usefulness of tests of isometric strength in differentiating back pain patients from healthy subjects, but have reported that a portion of the sample could not take part in the test, either because of the amount of strength required or because of pain (Biering-Sorensen, 1984; Hasue et al., 1980). In contrast to such tests, the test of flattening of the lumbar curve does not require a particular threshold of strength for participation because the subject controls the amount of torque exerted. Caution is necessary in isometric tests, however, because tolerance for the test may be low for persons who do not use correct breathing techniques to avoid the Valsalva maneuver, and who experience a resulting increase in blood pressure or decrease in cardiac output (Adamovich, 1984).

In this test of trunk strength, torque was produced by the muscles


Direction of Torque

Direction of Joint Motion

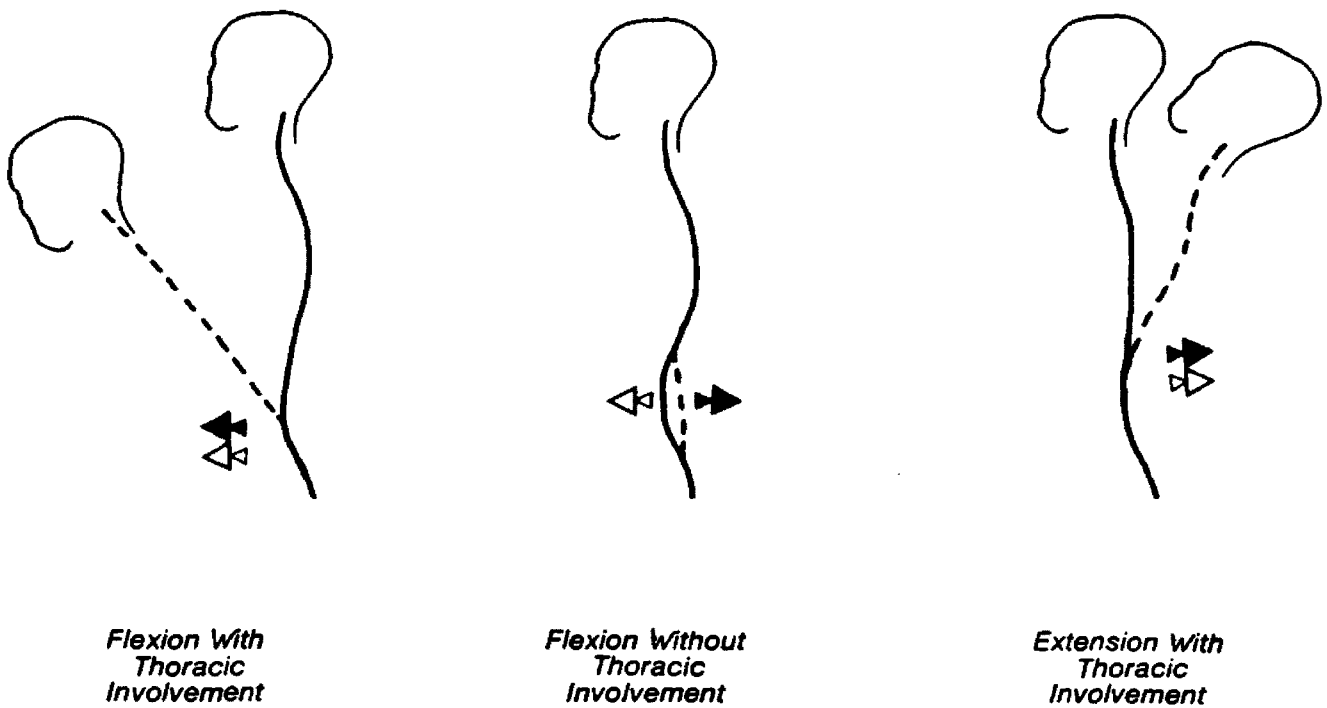


Figure 1. Effect of thoracic involvement on the direction of torque and on the type of intervertebral joint motion during lumbar flexion and extension.

which tilt the pelvis posteriorly. The muscles involved in the action of the posterior pelvic tilt included the abdominal muscles (the external obliques, the internal obliques, and the rectus abdominis) and the posterior pelvic muscles (the hamstrings and the gluteus maximus) (Lindh, 1980; Partridge & Walters, 1959; Wells, 1966). In addition, several researchers have suggested that certain muscles, including the sacrospinalis and the multifidus, may apply posteriorly directed force to the vertebrae themselves, particularly during lifting (Farfan, 1973; McGill & Norman, 1986).

In addition to the musculature which provides dynamic stability to the spine, the structural integrity of the lumbar spine is provided by the configuration of the intervertebral joints, the discs, ligaments, and fascia. In the normal healthy spine, the intervertebral joints move freely in flexion during posterior pelvic tilt (Day et al., 1984). However, joint disease can interfere with lumbar flexion (Macrae & Wright, 1969).

The contribution of the disc in intervertebral joint stability does not appear to be important in initial flexion. Its importance increases in the mid-range of flexion (Adams, Hutton, & Stott, 1980). Certain researchers have held that characteristics of the disc such as degeneration or varying height affect joint stability (Adams et al., 1980; Farfan, 1973), while others have found no consistent effect (Nachemson, Schultz, & Berkson, 1979).

Among the ligaments, the ligamentum flavum, which is highly elastic (Nachemson & Evans, 1968), appears to be the only source of ligamentous

joint stability in the initial range of flexion. Other ligaments are not brought into play until later in flexion (Adams et al., 1980; Lindh, 1980). Controversy exists concerning the importance of the lumbodorsal fascia in supporting the lumbar spine. Adams et al. (1980) suggested that it plays a major role, while McGill and Norman (1986), a minor role.

The torque applied in a posterior direction during flattening of the lumbar curve appears to be related to muscular torque applied either solely through posterior pelvic tilt, or in conjunction with force applied directly to the vertebrae. The role of the structures which maintain the integrity of the spine may be affected by several factors. Vertebral mobility may be affected by intervertebral joint disease. Characteristics of the discs, the condition of the ligamentum flavum, and action of the lumbodorsal fascia may also affect the integrity of the spine.

Statement of the Problem

The purpose of this study was to develop a test of isometric strength of flattening of the lumbar curve during posterior pelvic tilt while standing and to evaluate the reliability and validity of the test.

Although tests using varying pivot points to measure trunk strength have been useful in identifying strength deficits among low back pain patients, no tests have been developed which exclude the thorax. Exclusion of the thorax results in a unique test because it differs in the intervertebral joint motion and the direction of torque from both

tests of flexion and of extension which involve the thorax.

The measurement of torque in this test is important because it measures torque in a posterior direction, which acts to neutralize the forward torque encountered in lifting. The ability to reliably measure the isometric strength of flattening of the lumbar curve during posterior pelvic tilt while standing may prove useful to clinicians because it may give indication of the condition of the muscles, joints, discs, and fascia which provide structural integrity to the low back.

Delimitations

The study involved performance of the test by males, age 14-68, whose leg length at the greater trochanter was less than or equal to 91 cm. Generalizations resulting from this study apply to males with similar characteristics.

Limitations

1. Day-to-day reliability and intertester reliability studies involved small numbers of subjects.
2. Tests which involved comparisons of portions of the sample involved small numbers of subjects.
3. Certain subjects were not able to complete the test.

Assumption

1. Subjects gave maximum efforts during the tests of maximum isometric strength.

Methodology

Subjects

Pilot study. Four male volunteers, age 32-40, took part in the pilot study.

Main Back Strength Test (BST) study. Thirty male volunteers took part in the same-day, same-tester study. Four of the same-day, same-tester study subjects were retested in the day-to-day reliability study.

Participants' ages ranged from 14-68. The field of volunteers included men of varying age and activity levels. Men were ineligible whose leg length was greater than 91 cm at the greater trochanter, which was the maximum height of the axis of the apparatus. Subjects who missed three testing appointments were omitted from the study.

Five additional male volunteers, age 23-32, were tested in the intertester reliability study.

Testing Procedure

The protocol was reviewed by the University of Montana Institutional Review Board in order to protect the subjects' safety and privacy. Informed consent was obtained from each subject (Appendix A).

A confidential interview to obtain a history of low back pain which had affected activity levels was done. The interviewer asked whether the following activities had been reduced or had required assistance because of low back pain: lifting, sitting, standing, traveling, walking, sleeping, social activity, or putting on footwear. Subjects

identified the sites of low back pain on a drawing. The sites included seven areas: (A) first to third vertebrae and soft tissue, (B) fourth and fifth vertebrae and soft tissue, (C) sacrum and coccyx, (D,E) left and right flanks, and (F,G) left and right gluteal areas. The subject reported the time of the last experience of low back pain.

Identification of spinal sites. With the subject standing in natural posture and with feet comfortably apart at shoulder width, sites on the spine were located and marked with a water-soluble marker. Sites included the spinous processes of the seventh cervical (C7) and the sixth thoracic (T6) vertebrae; the intervertebral joints between the fourth and fifth lumbar vertebrae (L4L5) and between the fifth lumbar and first sacral vertebrae (L5S1); and points 5 cm above and 10 cm below L5S1. The distance from the hairline to C7 was recorded.

The identification of the spinal sites was documented by applying an architect's flexible ruler to the spine and shaping it to reproduce the spinal curves. The spinal sites were then marked on the ruler. A tracing of the curves and the spinal sites was made and kept with the subject's records.

Modified Schober Test. The Modified Schober Test (Macrae & Wright, 1969) was performed as a test of lumbar spinal mobility. The test measured the distance between two sites which were 15 cm apart when the subject stood in natural standing posture and which became further apart during lumbar flexion.

The subjects were instructed to bend forward from the hips as far as possible. The distance between the sites marked 5 cm below and 10 cm

above L5S1 was remeasured in the flexed position. The test was done three times and the mean of the three trials was recorded as the distance in the flexed position. The Modified Schober Test score was recorded as the flexed distance minus 15 cm (Macrae & Wright, 1969; Moran, Hall, & Ansell, 1979).

Maximum isometric test of flattening of the lumbar curve during posterior pelvic tilt. Subjects were tested for the maximum isometric strength of flattening of the lumbar curve during posterior pelvic tilt. This Back Strength Test (BST) was performed while standing erect with feet shoulder-width apart.

The subject's back was braced against two horizontal supports. The supports were constructed of 1½ in. (3.2 cm) wood doweling, adhered to a base which was concave on one side and flat on the other. The flat surface was covered with Velcro® for attachment to the felt backboard. The horizontal supports were placed at a level of T6 and at 5 cm below L5S1. The subject was braced 4 cm away from the backboard by the supports. A canvas belt was placed securely around the arms and chest at the T6 level. A second was secured anterior to the lower legs, just below the knees (see Figure 2).

Isometric torque was measured by the Cybex II® dynamometer with Dual Channel Recorder. The protocol for Cybex II use, outlined in Isolated-Joint Testing Exercise (Cybex, 1983), was adapted to the BST.

The Cybex was oriented facing the right side of the subject, with the fulcrum of the lever arm (the axis of the Cybex) at the greater trochanter of the right femur. The short input adapter of the Cybex was

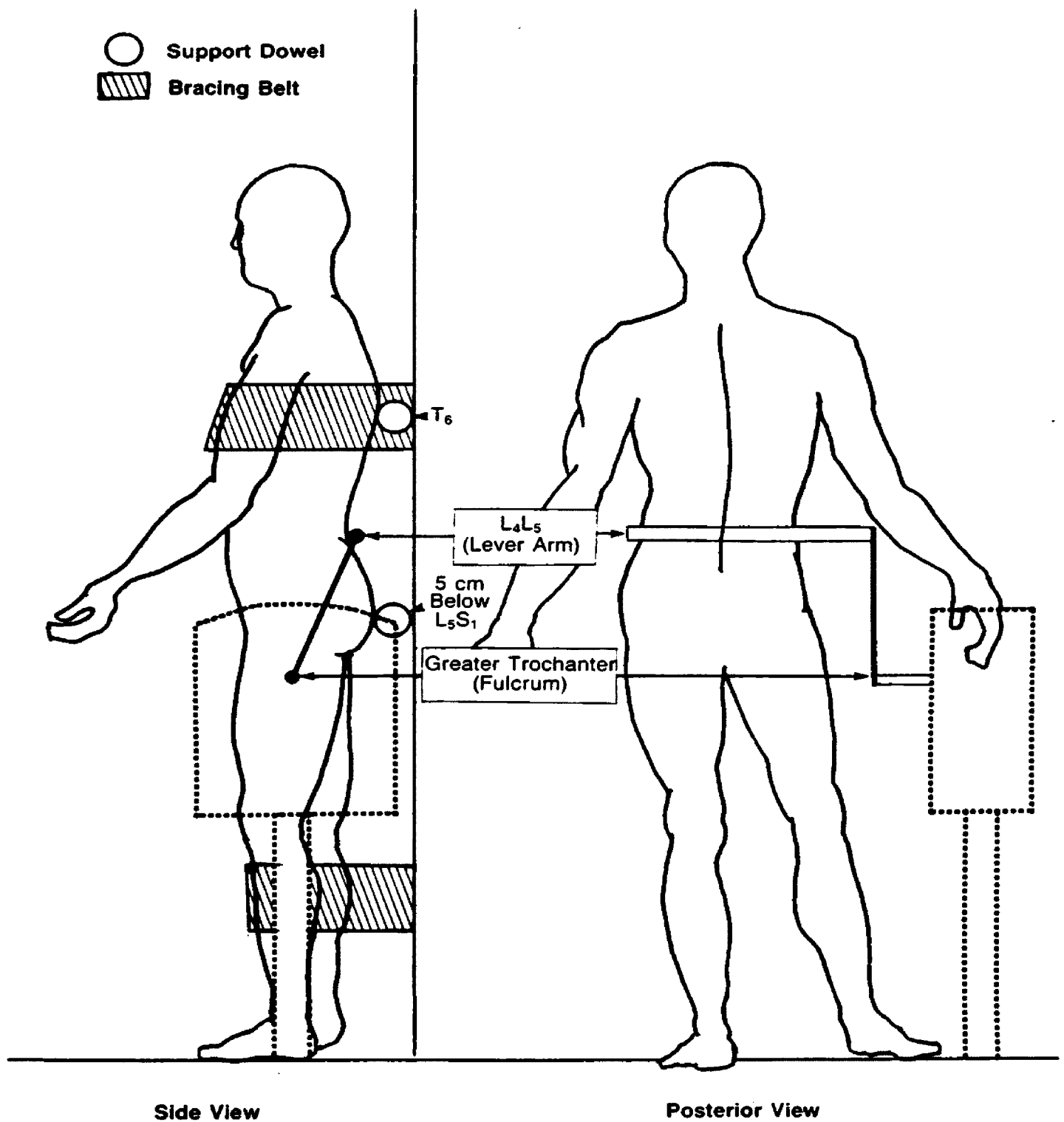


Figure 2. Positioning of the subject, fulcrum and lever arm of apparatus, support dowels, and bracing belts.

connected to the shoulder testing accessory. The horizontal bar of the shoulder testing accessory was positioned across the back of the subject at the level of L4L5.

In order to ensure that each trial involved similar positioning, the angle of the lever arm which reached from the fulcrum at the greater trochanter to the horizontal bar resting against the low back at L4L5 was standardized to the angle used in the first trial of the first test (see Figure 3). This angle was designated the deflection angle. The accuracy of the angle was maintained within one minor division on the recording graph paper, equal to 3° , on all subsequent tests. On the Dual Channel Recorder, the deflection of the position angle stylus away from its position when the lever arm was vertical reflected the testing position (see Appendix B, Standardization of Position Angle).

When tests were repeated on individuals during day-to-day and intertester protocols, the deflection angle, shoulder testing accessory length, and height of the axis of the Cybex used in the original test were duplicated. In addition, the tracing of the original spinal curve with sites marked, which had been recorded during the first test, was transferred to the architect's flexible ruler, and the sites were then marked on the subject's back. Accuracy in using the site of C7 as the anchor point from which to measure the other sites was enhanced by measuring the distance from the hairline to C7, which had been recorded in the original test.

Instructions to subjects. Standardized instructions in producing the isometric maximum effort during posterior pelvic tilt by pressing

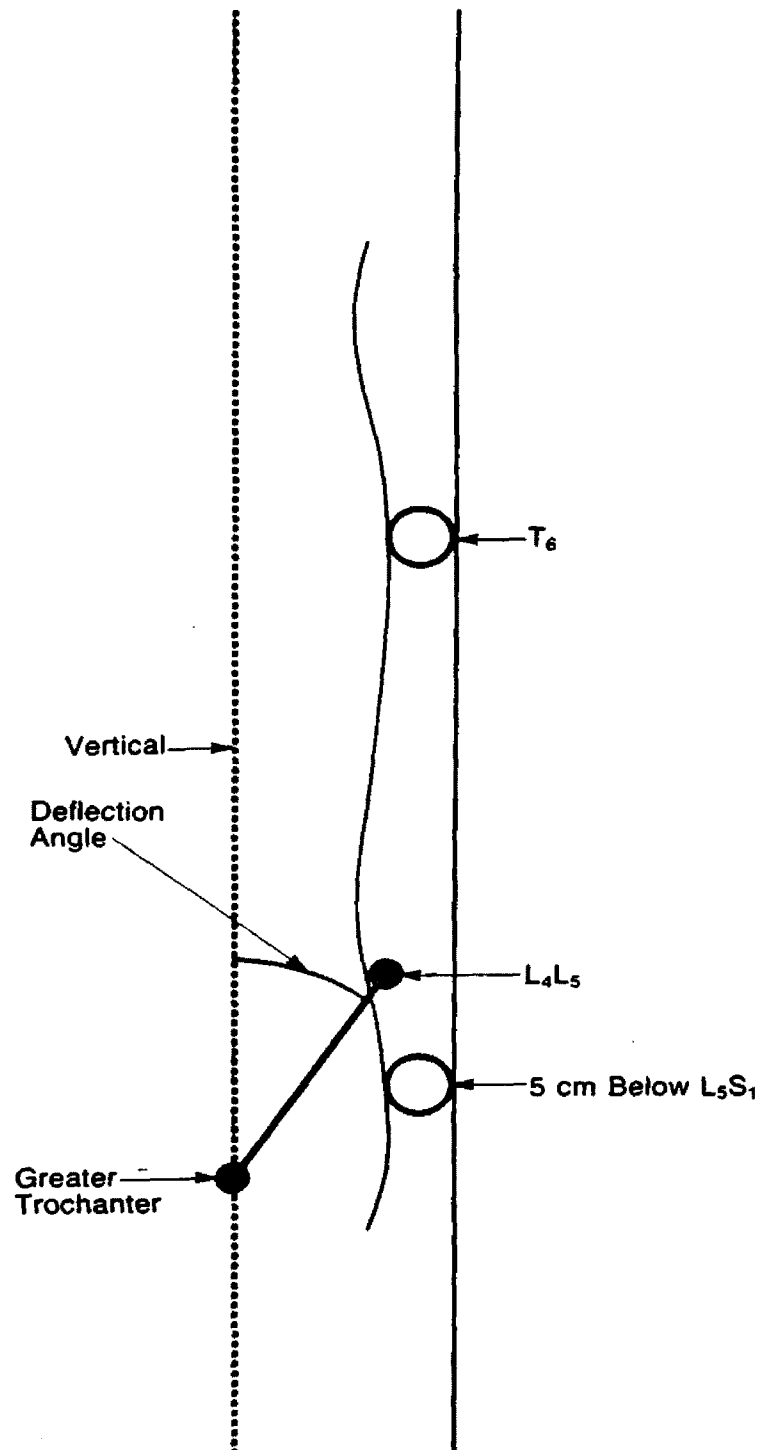


Figure 3. Deflection angle in relation to the vertical and to anatomical sites.

the lumbar area against the lever arm were given (see Appendix C, Standardized Instructions to Subjects). During the training attempts, the subjects were allowed to view the movement of the torque channel stylus of the Dual Channel Recorder to observe their success in exerting torque upon the testing machine bar.

Subjects were required to maintain a standardized form in producing the isometric effort. The upper back was required to remain vertical, braced against the dowel at T6. The lower back stayed against the lower dowel located 5 cm below L5S1. Feet remained flat on the floor. During the training attempts, verbal feedback was given to subjects to help them maintain the proper form.

Pilot Study Format

The pilot study took place in the Physical Therapy Department of St. Patrick Hospital, Missoula, MT. Calibration of the Cybex II dynamometer with Dual Channel Recorder was maintained by the hospital's physical therapy staff. No significant corrections were necessary during the pilot study. Informed consent and an interview to obtain a history of low back trouble were completed. Identification of spinal sites and the Modified Schober Test were then performed.

Following positioning of the subject and apparatus and administration of the standardized instructions, the pilot subjects performed the maximum effort 10 times with 60 s between trials. Following each trial, the starting positions of the deflection angle and torque baseline were reestablished. The bracing belts were checked for

tightness every three trials. Subjects were permitted to view the stylus which recorded the torque.

Back Strength Test Study Format

Main Back Strength Test study format. The main BST study used the facilities of the Physical Therapy Department of Missoula Community Medical Center. The professional staff of the department performed the calibration of the Cybex II with Dual Channel Recorder. No calibration was necessary during the main study, including the same-day, same-tester; day-to-day; or intertester studies. No calibration was necessary between repeated tests of individual subjects in the day-to-day or intertester studies.

The format of the administration of the informed consent, history interview, identification of spinal sites, positioning, and standardization instructions was the same as that of the pilot study. During the main study, a total of five trials in correct form were done, with 60 s between trials. Subjects were permitted to view the stylus only during the first 3 trials. During the fourth and fifth trials, visual feedback from the stylus was prevented. Trials performed with incorrect form were excluded. Verbal feedback concerning the required form was then given and the trial was repeated until five trials in correct form were obtained for each of the subjects.

Day-to-day reliability study format. For the day-to-day reliability study, 4 subjects were retested one week after their initial test, using the same methodology. Each received a brief review of the

standardized instructions before the second set of trials.

Intertester reliability study format. The author trained three registered physical therapists using the Retest Protocol (Appendix D), Standardized Instructions to Subjects (Appendix C), and Methodology, and demonstrated the apparatus to the testers. Each subject was tested three times on the same day by two testers and the author. Steps of the methodology duplicated by each tester included identification of spinal sites, positioning of the apparatus, instruction of the subjects, and administration of the BST with screening of incorrect form. Testers were not permitted to view the tests or the results of other testers.

Statistical Treatment of the Data

To identify the influence of repeated trials on performance, descriptive statistics were used to characterize the data of the 4 pilot-study subjects. The Treatments by Subjects analysis of variance (ANOVA) available in the Statistics with Finesse software for Apple® computer by Bolding (1984) was used to identify differences among and between subjects.

Descriptive statistics were used to compare characteristics of the sample of 30 volunteers to those of a sample of 928 subjects studied by Biering-Sorensen (1983) in similar research. The purpose was to ascertain whether the volunteer sample resembled a sample found to be representative of a community.

Systematic influence due to age, anthropometric, or apparatus factors was screened using the Pearson correlation and Spearman Rho rank

order coefficients.

The main BST study results were evaluated for differences among and between subjects using the Treatment by Subjects ANOVA. Because differences between individuals were expected, post hoc statistical tests were not computed when statistically significant differences were calculated between subjects. Descriptive statistics and the t-test for difference between means were used to evaluate changes in performance between test trials with, and test trials without, visual feedback.

To determine day-to-day reliability, due to the small sample size (N = 4), the Spearman Rho rank order coefficient was used to evaluate the stability of performance during retesting.

In the intertester reliability study, determination of the differences among testers required Kendall's coefficient of concordance in evaluating the data from the testing of the 5 subjects by three testers each.

Descriptive statistics and reliability coefficients were compared in order to evaluate the stability of several trial scores to be used as criterion scores.

Evaluation of the ability of the BST to measure clinically important changes in strength was done by comparing the reliability of the criterion scores with the level of clinical sensitivity needed.

Validity of the BST was investigated by comparing the differences between mean strength scores obtained by groups of subjects, using the t-test for differences between means. Subjects were grouped according to mobility of the lumbar spine and to history of low back pain.

Results and Discussion

Pilot Study

In order to identify the influence of repeated trials on performance during the pilot study, Trials 1-10 were compared. The highest scores, as shown by the mean and range of scores, were obtained in the first five trials (see Table 1). Individual data are in Appendix E, Table E-1.

Table 1. Pilot Study Mean, Standard Deviation, and Range of Scores (ft-lb) of Ten Trials.

Trial ^a	<u>M</u>	<u>SD</u>	Range	Trial ^a	<u>M</u>	<u>SD</u>	Range
1	11.3	6.80	4-18	6	10.8	5.68	3-15
2	10.3	4.86	4-15	7	11.5	7.19	1-17
3	11.0	5.23	4-15	8	10.0	6.27	2-17
4	13.8	6.02	8-22	9	12.0	5.42	4-16
5	13.3	3.77	9-18	10	12.5	6.81	3-19

^an = 4.

Scores for individual subjects showed that learning, fatigue, and motivation may have influenced scores (see Figure 4). Subject A appeared to increase scores through the first five trials, then, after a lower score on Trial 6, to stabilize, displaying a learning process. Subject B maintained a stable score throughout the 10 trials, without

displaying measurable fatigue or learning. Subjects C and D displayed more variability. Subject C increased from Trial 1 to Trial 4, then decreased through Trial 8, before increasing again. These results could indicate a learning curve followed by fatigue. However, with the increase at the 9th and 10th trials, it is more likely that motivation had temporarily lapsed. Subject D increased from Trial 1 to Trial 5, then decreased, displaying evidence of fatigue.

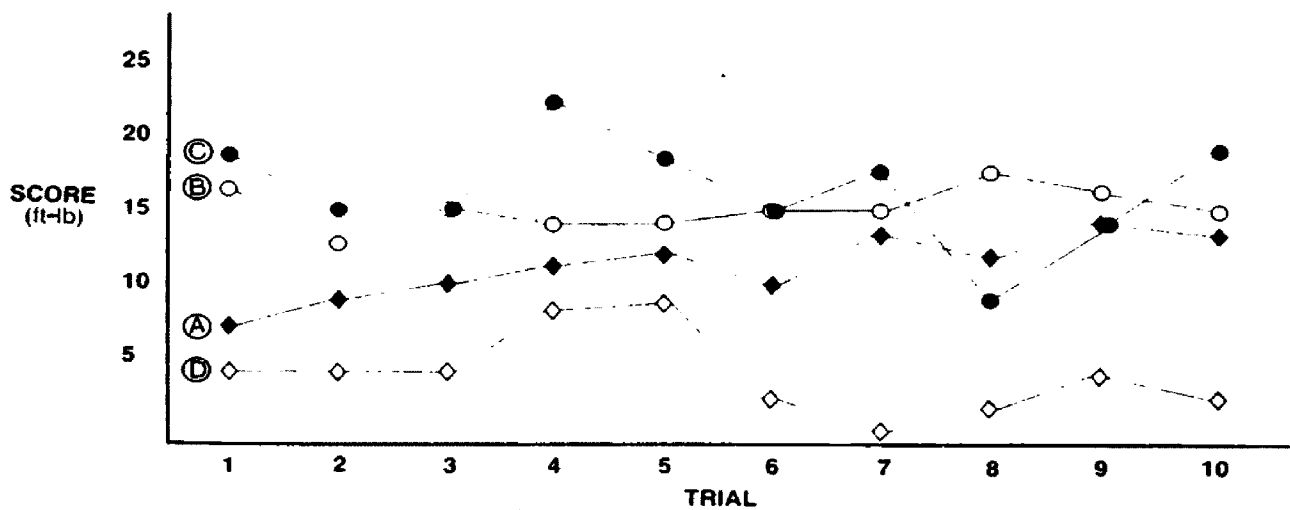


Figure 4. Pilot study scores on ten trials by four subjects.

Trials 1-5 afforded time for learning effects to stabilize while Trials 6-10 displayed variability, possibly due to fatigue or decreasing motivation. Therefore, the first five trials were used for the BST study, to minimize the effects of fatigue and declining motivation.

The pilot data were evaluated for the ability of the test to differentiate subjects while providing stable scores for individuals. Results of the Treatment by Subjects ANOVA are displayed in Table 2.

There was a significant difference among subjects ($p = .0001$) without significant difference within each subject's performance ($p = .4448$).

Table 2. Pilot Study Treatment by Subjects Analysis of Variance.

Source	<u>df</u>	<u>SS</u>	Variance estimate	<u>F-ratio</u>	<u>p</u>
Among	3	877.27	292.42	48.27	.0001
Within subjects	36	218.10	6.06		
Treatments	9	55.63	6.18	1.03	.4448
Residual	27	162.48	6.02		
Total	39	1095.38	28.09		

As a post hoc test following the ANOVA, the Scheffe test was used to identify the subjects among whom the differences were greatest. Two of the subjects were not significantly different in strength (Subjects B and C), while there were significant differences among the other pairs of subjects.

The means of BST scores of subjects who had experienced an episode of acute or recurrent pain, which had caused reduced activity during the last one month or the last six months, were compared with the mean scores of those who had not. No pilot subject had experienced an episode during the last month. During the last six months, only Subject C had had an acute episode. His mean BST score of 16.2 ft-lb (22.0 N-m)

was higher than the mean of the other subjects, 10.1 ft-lb (13.7 N-m). Although the sample is small and no conclusions can be drawn, no decline was observed in the BST scores for the pilot subject with an occurrence of low back pain in the last six months.

The pilot subjects were also categorized according to their lumbar spinal mobility as measured by the Modified Schober Test and mean BST scores were compared. All subjects were within 1 cm of the predicted norm for age and gender in spinal mobility (Macrae & Wright, 1969; Moran et al., 1979). Therefore, differences in the BST scores were apparently not reflective of differences in spinal mobility for the 4 pilot subjects.

Main Back Strength Test (BST) Study

Using descriptive statistics, characteristics of the sample of 30 volunteers in the same-day, same-tester study were compared with characteristics of a sample of subjects which had been found to be representative of a community in another study by Biering-Sorensen (1983). Biering-Sorensen had sampled 928 persons comprising 82% of all persons 30, 40, 50, and 60 years of age in a Denmark community. The BST study sampled volunteer males, aged 14-68, with 4 subjects (13%) under 30 years of age and one subject above age 60. Despite the difference in age groups between the two studies, mean height and weight were similar: 177 cm (69.7 in.) and 78.1 kg (171.9 lb) for the BST study, and 175.2 cm (69.0 in.) and 76.8 kg (169.0 lb) for the Biering-Sorensen study.

A comparison of reported low back pain rates also showed

similarities in the two samples. The two studies contained similar categories to identify persons who had experienced reduced activity due to low back pain. The BST study categorized persons who had experienced low back pain by whether the pain had caused a reduction in activity. The Biering-Sorensen study contained a similar category of persons who had been impeded in their daily work, including housework, due to low back pain. Both studies reported that 40% of the men had experienced low back pain which had caused reductions in activity.

In regard to the incidence of pain in a one-year period, both studies had similar rates. In the BST study, 30% of the subjects reported that they had experienced such pain in the previous year. This compared with a rate of 25% in the Biering-Sorensen study.

Caution must be observed in generalizing from a small sample. However, the similarity of the BST study sample to the larger sample suggests that the sample obtained in the BST study was not an atypical group in regard to height, weight, and incidence of low back pain.

Systematic influences. In order to investigate whether the performance on the BST was systematically influenced by age, anthropometric, or apparatus factors, Pearson correlations were computed. Comparisons between the individual's mean BST score and age, height, weight, apparatus height to the axis, and the deflection angle were computed (see Table 3). Since a deflection angle which placed the moment arm more perpendicular to the force being exerted in a posterior direction could be associated with higher scores (Wiktorin & Nordin, 1986), angles closer to the vertical, or 0°, might have been found to be

associated with higher scores. However, there was not a significant correlation between any of the factors and the BST scores, indicating that there was not a systematic influence on the BST by these factors.

Table 3. Pearson Coefficients of Correlation (r) of Physical and Apparatus Factors with Mean Back Strength Test Scores.

Factor	n^a	r	p
Trochanter height	23	.15	.25
Height to L4L5	23	.05	.41
Deflection angle	23	.28	.07
Age	30	-.01	.48
Subject height	30	.18	.18
Weight	30	-.19	.16

Note. Mean Back Strength Test scores were for Trials 1-5.

^aApparatus factors were not recorded for seven subjects.

In addition, the length of the shoulder testing accessory of the Cybex apparatus, which was used as the moment arm, was analyzed because a longer apparatus moment arm might influence the score systematically and could be associated with higher scores. Since settings of length were not continuous on the apparatus, the Spearman Rho rank order coefficient was calculated, comparing the accessory length with the individual's mean BST score. The coefficient, corrected for ties, was -.02, indicating that there was no significant systematic variability produced by the length of the moment arm of the apparatus.

Analysis of main BST study scores. The individual data ($N = 30$) for the main BST study (the same-day, same-tester data) are in Appendix E, Table E-2. The mean score for all subjects was 11.8 ft-lb (16.0 N-m) with a standard deviation of 5.79 ft-lb (7.85 N-m). Scores ranged from 1 to 26 ft-lb (1.4 to 35.3 N-m). For individual subjects, the mean of five trials ranged from 2.8 to 23.2 ft-lb (3.8 to 31.5 N-m) and the standard deviations from 0.45 to 2.97 ft-lb (0.61 to 4.03 N-m). High scores for individuals ranged from 4 to 26 ft-lb (5.4 to 35.3 N-m).

The Treatments by Subjects analysis of variance (see Table 4) indicated a significant difference among subjects, $F(29, 120) = 52.37$, $p = .0001$, but not within each subject's trials, $F(4, 116) = 1.14$, $p = .3427$. This showed that the BST provided useful information on differences in strength between individuals, while maintaining consistency within each subject's performance. Because differences between individuals on strength tests were expected, post hoc statistical tests were not performed.

Comparison of Trials 1-5. Among the five trials, the means ranged from 11.4-12.1 ft-lb (15.5-16.4 N-m) and the standard deviations from 5.39-6.08 ft-lb (7.31-8.24 N-m) (see Table 5). The means of all the trials were similar, and, as the ANOVA showed, there was not a significant difference in the repeated trials within each individual's performance compared to that among individuals.

In order to compare the methods of receiving and not receiving visual feedback, the difference between the means of Trials 1-3 and the

Table 4. Back Strength Test Same-Day, Same-Tester Treatments by Subjects Analysis of Variance.

Source	<u>df</u>	<u>SS</u>	Variance estimate	<u>F</u> -ratio	<u>p</u>
Among	29	4621.57	159.36	52.37	.0001
Within subjects	120	365.20	3.04		
Treatments	4	13.77	3.44	1.14	.3427
Residual	116	351.43	3.03		
Total	149	4986.77	33.47		

Table 5. Back Strength Test Mean, Standard Deviation, and Range for Five Trials During Same-Day, Same-Tester Study.

Trial	<u>M</u> ^a	<u>SD</u>	Range
1	11.4	5.39	3-20
2	11.5	5.87	3-23
3	12.0	5.90	3-24
4	12.1	6.08	1-24
5	12.2	6.02	1-26

^aft-lb.

means of Trials 4-5 was calculated. There was not a significant difference between the methods, $t = 1.25$, $N = 30$, $p = .11$.

In addition, performance in the main BST study was compared to the pilot study to observe the effect of the change in feedback. In the pilot study, no subjects performed their lowest scores on Trials 4 or 5. The only decline from Trial 1 to Trials 4 and 5 was a 2 ft-lb (2.7 N-m) decline. In the main BST study, however, 7 subjects (23%) performed their lowest scores in Trials 4 or 5. Most subjects followed the pattern described in the pilot study of increasing scores and stabilizing performance in Trials 4 and 5, with 13 subjects (43%) in the main study achieving their highest scores on Trials 4 or 5.

Although the pilot study was small in scope ($N = 4$), the difference between the pilot data and the main study data indicated that in the main study, certain subjects did not maintain their performance during Trials 4 and 5. The change in method of stopping visual feedback appeared to affect these individuals.

Stability of the scores was adequate and Trials 1-5 have similar results. However, in the clinical setting, the influence of visual feedback should be considered. Learning to exert maximum isometric strength of flattening of the lumbar curve during posterior pelvic tilt may be initially enhanced by visual feedback. However, the ability to maintain the skill without visual feedback cannot be assumed, and additional coaching of certain individuals may be necessary. Practice without feedback may increase the ability to generalize the skill to daily life.

Day-to-Day Reliability Study

The Spearman Rho rank order test was used to examine the reliability of the day-to-day testing. The individual results for the day-to-day reliability study are in Appendix E, Table E-3. The reliability coefficients according to the criterion scores were: mean of Trials 1-3, 0.80; mean of Trials 4-5, 1.00; mean of Trials 1-5, 0.80; high score in five trials, 0.80. While interpretation of the data is done with caution due to the small number of subjects ($n = 4$), the Spearman Rho rank order test showed the protocol to be reliable in day-to-day testing, particularly when the mean of Trials 4 and 5 was used as the criterion score.

The main sources of variability investigated in day-to-day reliability were the internal influences on the performance of the subject, such as influences on motivation, on concentration, or on learning of the skill. Most other factors, such as identification of spinal sites and alignment of the apparatus, were held constant by the methodology which provided for systematic duplication of the original testing conditions. In addition, use of the same tester held constant the variability due to tester judgment.

Although day-to-day reliability was good, two methodological elements may have increased the variability. First, the complete instructions to the subject were abbreviated during the retest which took place one week later. Repeating the exact instructions might have been able to produce more reliable results on retest. Second, one volunteer subject was included in the retest while 3 subjects were

randomly selected. Since a different level of motivation may have been present in the volunteer, restricting subjects during retesting to those who were randomly selected might have produced a higher reliability coefficient.

Intertester Reliability Study

In order to investigate the intertester reliability of the BST, 5 additional subjects were tested by three testers, and scores were evaluated using Kendall's coefficient of concordance, corrected for ties (see Appendix E, Table E-4, for individual results). Reliability varied depending upon the criterion score used, with the high score in five trials providing the most reliability ($W = .97$). The coefficients for the criterion scores of mean of Trials 1-3, mean of Trials 4-5, and mean of Trials 1-5 were .83, .83, and .92, respectively. Although caution is necessary in interpreting the data due to the small sample, the intertester study showed the BST to be reliable among testers.

Sources of variability among testers in the strength study arose mainly from the judgment of the testers in screening correct form and from the differences in teaching of the correct form by different testers (Safrit, 1976). The main influence on the BST scores which was tested was the judgment of the testers in screening correct form, since the influence of different testers in instructing the subject was minimized by the short time between testers.

Evaluation of Criterion Scores

Evaluation of criterion scores provided information on the stability of scores under varying conditions. Changes in raw scores for individuals under the three testing conditions (same-day, same-tester; day-to-day; and intertester) are displayed in Table 6. In addition, the change in the criterion scores and the reliability coefficients of the day-to-day and intertester conditions are shown in Table 7.

Table 6. Change in the Scores of Individuals Under Same-Day, Same-Tester; Day-to-Day; and Intertester Conditions.

Condition	<u>N</u>	No. of scores ^a	Change ^b	<u>SD</u> range ^c	Average ^d <u>SD</u>	<u>SE_M</u> ^e
Same-Day, Same-Tester	30	5	2- 9	0.45- 2.77	1.59	0.29
Day-to-Day	4	10	4-11	1.05- 2.82	1.94	0.97
Intertester	5	15	5-14	0.71- 3.91	1.58	0.71

^aTotal number of scores for an individual.

^bRange of change among subjects throughout testing conditions, in ft-lb.

^cRange of SD among subjects.

^dAverage SD among subjects.

^eStandard error of the mean.

Table 7. Range of Change and Reliability Coefficients of Criterion Scores of Individuals for Day-to-Day and Intertester Conditions.

Condition	No. of scores	<u>M</u> of			High score in five trials
		Trials 1-5	Trials 1-3	Trials 4-5	
Day-to-Day	2				
Change ^a		3-6	2-6	2- 5	2-5
Reliability ^b		0.80	0.80	1.00	0.80
Intertester	3				
Change ^a		3-7	4-6	3-13	2-5
Reliability ^c		0.92	0.83	0.83	0.97

^aft-lb.

^bSpearman Rho rank order coefficient.

^cKendall's coefficient of concordance.

In the same-day, same-tester study (see Table 6), changes in an individual's scores varied less than in the day-to-day or intertester conditions which had introduced sources of variability from the passage of time or from tester differences. In the intertester study, an individual's score change ranged up to 14 ft-lb (19.0 N-m). However, only in one instance did the change reach 14 ft-lb (19.0 N-m), when a systematic error in setting the deflection angle was noted. All other changes for the intertester study in an individual's scores ranged to 10 ft-lb (13.6 N-m).

The range of standard deviations of scores for individuals was

smaller for the same-day, same-tester condition. The averages of the standard deviations were similar in the intertester and the same-day, same-tester studies.

Reporting of mean scores and high scores narrowed the range of change in a subject's scores, except in the intertester study for mean of Trials 4-5 (see Table 7). Reliability in the day-to-day study was highest for the mean of Trials 4-5 and in the intertester study, for the high score in five trials.

The decision on the most appropriate criterion score, then, varies with the use of the test. In a clinical setting, where the same tester could be expected to retest a patient, the choice of criterion scores does not appear to be as crucial as when intertester reliability is involved. The mean of Trials 4-5 provided adequate reliability when only one tester was involved in day-to-day testing. However, overall, the high score in five trials provided the most stability, with changes in an individual's score of 2-5 ft-lb (2.7-6.8 N-m) in both day-to-day and intertester testing, and with the highest intertester reliability coefficient.

Evaluation of Clinical Usefulness

Clinical usefulness of the BST is determined by the test's sensitivity in discerning a level of change which is clinically important and which can be distinguished from random change due to the test's error level. Since the mean score for all subjects was 11.8 ft-lb (16.0 N-m), with a standard deviation of 5.79 ft-lb (7.85 N-m),

a sensitivity of approximately 6 ft-lb (8.1 N-m) is sufficient to enable the test to differentiate among persons with low, medium, or high strength scores. Thus, 12 ft-lb (16.3 N-m) can be considered average strength; and ± 1 standard deviation, or 6-17.9 ft-lb (8.1-24.3 N-m), can be considered medium strength; 0-5.9 ft-lb (0-8.0 N-m), low strength; and 18-23.9 ft-lb (24.4-32.4 N-m), high strength.

As the data in Table 6 show, the standard deviation of an individual's scores ranged from 0.45-2.77 ft-lb (0.6-3.8 N-m) in the same-day, same-tester study; and in the day-to-day and intertester studies, ranged up to 2.82 (3.82) and 3.91 (5.30) ft-lb (N-m), respectively. The averages of the standard deviations for all three testing conditions were less than 2 ft-lb (2.7 N-m), with a standard error of the mean of 0.29-0.97 ft-lb (0.39-1.32 N-m). Given this level of variability in day-to-day and intertester scores, progress by an individual through strength levels in 6-ft-lb (8.1-N-m) increments of low, medium, and high scores can be discerned using the BST.

In addition, use of the criterion scores (see Table 7), particularly the high score in five trials, increased the clinical usefulness of the BST. The range of change of the high score in five trials was 2-5 ft-lb (2.7-6.8 N-m). This range permits clinical progress from low to medium, or high, scores scores to be reliably measured.

Criterion Validity

Criterion validity (Isaac & Michael, 1983) was explored by

comparing the scores obtained in the BST study with those obtained in another test of isometric trunk strength (Thorstensson & Arvidson, 1982). That research measured torque exerted per kilogram of body weight during isometric trunk flexion on a horizontal plane. The mean torque value during isometric flexion, with the pivot center at the greater trochanter, was 2.4 N-m/kg body weight.

In order to compare the Thorstensson and Arvidson study scores with the BST study scores, the difference in the lengths of the lever arms in the two studies was considered. The lever arm in the Thorstensson and Arvidson study was 0.44 m, while the mean lever arm length in the BST study was 0.20 m. Adapting the Thorstensson and Arvidson value of 2.4 N-m/kg body weight at a lever arm length of 0.44 m to the mean lever arm length of the BST study (0.20 m), the equivalent value was 1.1 N-m/kg body weight. In the BST study, the mean isometric torque during pelvic tilt was 16.0 N-m (11.8 ft-lb). Adjusted for the mean weight of the subjects of 78.1 kg (172 lb), the value of the torque was 0.2 N-m/kg body weight.

The amount of torque exerted during the isometric pelvic tilt in the BST study (0.2 N-m/kg body weight) was 18% of the torque exerted at an equivalent lever arm length during isometric flexion with thorax involvement in the Thorstensson and Arvidson study (1.1 N-m/kg body weight). The criterion validity was supported since the BST, which prevented thorax involvement, was expected to generate less torque than the isometric flexion test which involved the thorax and recruited a greater number of muscles.

Construct Validity

Modified Schober Test. Construct validity was examined by investigating the ability of the BST to distinguish subjects based on their lumbar spinal mobility as measured by the Modified Schober Test. Subjects were grouped according to their mobility scores, and the mean strength scores achieved by the groups were compared using the t-test for differences between means (see Table 8).

Table 8. Mean Back Strength Test (BST) Scores of Subjects According to Modified Schober Test Scores and Deviation from Predicted Modified Schober Scores.

Modified Schober Test	<u>n</u>	<u>M</u>	<u>SD</u>	Range	<u>t</u> -value	<u>p</u>
Scores ^a						
9 to 9.9	3	7.7	3.76	1-14	-1.51	.07
6 to 8.9	24	12.8	5.63	1-26	1.68	.05
5 to 5.9	3	7.2	2.84	4-12		
Deviation from predicted scores ^a						
+2 to +2.9	3	7.7	3.78	1-14	-1.54	.07
-1 to +1.9	24	12.9	5.59	1-26	-1.88	.03
-2 to -1.1	3	6.7	1.94	4-10		

^acm.

Two measures of Modified Schober Test scores were used, the actual score (skin distraction minus 15 cm) and the deviation from the

predicted score for age and gender. The t-test for differences between means found that subjects in the central groups tended to have BST scores which were higher than subjects in either the higher or lower mobility ranges. Probability ranged from .03 to .07.

Although the data are interpreted with caution due to the small sample, the validity of the BST is upheld by the differences in strength scores among persons of varying lumbar mobility. The group with higher mobility had a mean BST score of 7.7 ft-lb (10.4 N-m), while the central group had a mean BST score of 12.8 ft-lb (17.4 N-m) [t(25) = -1.51, p = .07]. The group with lower mobility also differed in strength from the central group in mean strength scores [t(25) = -1.68, p = .05].

Theoretically, both high and low ranges of lumbar vertebral mobility could be expected to affect the ability to exert posterior force in the lumbar area during posterior pelvic tilt. Low mobility could restrict the posterior movement of the lumbar curve while instability associated with increased mobility could interfere with the effective exertion of force. The latter condition may have been a factor in the finding of the Biering-Sorensen (1983) study in which increased mobility of the lumbar spine, as measured by the Modified Schober Test, was a significant predictor of low back problems.

Although the Modified Schober Test is useful in grouping subjects, it should be noted that the mobility test is not identical with the BST. The Modified Schober Test is highly valid as a measure of vertebral lumbar mobility. The association between the scores indicates that one of the components influencing the BST scores is the mobility of the

lumbar spine.

History of low back pain. Construct validity of the BST was further explored by investigating its ability to distinguish subjects based on their history of low back pain. Mean BST scores of groups with pain were compared to those without, using the t-test for differences between means. The group of persons with an acute or recurrent episode of low back pain, which had caused reduced activity in the last month (n = 4) or in the last 6 months (n = 5), had a lower mean score than the group without pain (see Table 9). However, the difference was not statistically significant.

Table 9. Mean Back Strength Test Scores of Subjects According to History of Character of Low Back Pain.

History of low back pain	<u>n</u>	<u>M</u>	<u>SD</u>	Range	<u>t</u> -value	<u>p</u>
During last month						
Acute or recurrent	4	8.8	3.5	4-19	-1.19	.12
None	24	12.4	5.8	3-26		
Continuous	2	10.1	7.2	4-18	0.54	.30
During last 6 months						
Acute or recurrent	5	9.1	3.1	4-19	-1.23	.11
None	23	12.5	5.9	3-26		
Continuous	2	10.1	7.2	4-18	0.54	.30

^aComparison of means was between group with pain and group without pain.

Episodes of low back pain in the previous month demonstrated the influence of duration of the episode on BST scores. The Pearson correlation was used to evaluate how BST scores of persons with low back pain in the last month varied with the duration of the episode for the 3 subjects who reported duration of the episode. Correlations with duration were calculated for three criterion scores. The correlation and probability varied among the criterion scores which included the mean of Trials 1-3 [$r(1) = -.97$, $p = .07$]; the mean of Trials 4-5 [$r(1) = -.99$, $p = .04$]; and the mean of Trials 1-5 [$r(1) = -.99$, $p = .04$]. Although the correlation is statistically significant, and there is an inverse relationship between the duration of the episodes during the last month and the BST scores, the small sample size must be considered in weighing the importance of this correlation.

The influence of the site of pain was examined by comparing mean BST scores of groups of persons with histories of pain in particular sites to those without such pain, using the t -test for differences in means (see Table 10). Sites identified in the study included: (A) first to third lumbar vertebrae and soft tissue, (B) fourth and fifth lumbar vertebrae and soft tissue, (C) sacral and coccygeal areas, (D,E) left and right flank areas, and (F,G) left and right gluteal areas (Biering-Sorensen, 1983).

The group of persons ($n = 3$) with gluteal pain or pain radiating to the gluteal region (areas F and G) had a significantly lower mean score than the group without [$t(25) = -1.99$, $p = .03$]. The group of persons with low lumbar, paraspinal pain (area B or C) during either the last

month or last 6 months had a mean BST score which was not significantly different from the group without such pain.

Table 10. Mean Back Strength Test Scores of Subjects According to History of Site of Low Back Pain.

History of low back pain	<u>n</u>	<u>M</u>	<u>SD</u>	<u>t-value</u>	<u>p</u>
Lower lumbar, paraspinal pain (Fourth and fifth lumbar and/or sacral and coccygeal)					
During last month					
Present	2	14.5	1.0	0.71	.24
Not present	28	11.6	5.8		
During last 6 months					
Present	3	13.1	2.6	0.12	.34
Not present	27	11.6	5.9		
Gluteal pain					
During last month					
Present	3	5.9	0.9	-1.99	.03
Not present	27	12.4	5.5		
During last 6 months					
Present	3	5.9	0.9	-1.99	.03
Not present	27	12.4	5.5		

As emphasized earlier, the small number of subjects reporting low back pain in the study requires that the data be interpreted with

caution. The validity of the BST is supported by the tendency for persons with low back pain to score lower on the test, since this is compatible with reports in the literature of lower strength scores among persons with low back problems (Thorstensson & Arvidson, 1982).

Nachemson and Lindh (1969) held that such weakness was an effect of the duration of incapacitation rather than a cause of low back problems, finding no weakness in persons incapacitated less than a month, while other authors have noted a history of surgery or sciatica to influence isometric strength in flexion (McNeill et al., 1980). The influence of duration of episode was discernible in the BST scores.

The element of sites of low back pain having varying effects on strength upheld the validity of the BST. The ability of the low back to exert torque in a posterior direction may be affected differently when pain is located in different areas.

Summary, Conclusions, and Recommendations

Summary

This study reviewed the importance of the ability of the low back to exert torque in a posterior direction. Tests of trunk strength currently in use to measure torque in flexion and extension of the upper body involve the thorax and the large muscles of flexion and extension. Tests of more specific motions have been found useful in identifying strength deficits among low back pain patients.

The Back Strength Test was developed to measure the strength of flattening of the lumbar spine during pelvic tilt while standing. The test did not involve thoracic movement. It measured the posteriorly exerted torque in the lumbar area with the thorax held stationary. The components of trunk strength and spinal integrity involved in exerting torque in the lumbar area in a posterior direction during the posterior pelvic tilt were discussed.

Following testing of 30 male volunteers who performed five trials of the BST, the reliability and validity of the test were investigated. Calculation of the Treatment by Subjects analysis of variance found the difference among subjects to be significant [$F(29, 120) = 52.37$, $p = .0001$]. Day-to-day reliability of a subsample ($n = 4$) indicated that BST scores were reliable (Spearman Rho rank order coefficient = .80 to 1.00). An intertester reliability study using three testers ($N = 5$) found Kendall's coefficient of concordance to indicate good reliability ($W = .83$ to $.97$). Sensitivity of the test was adequate to differentiate

clinical progress for individual patients.

Criterion validity of the test was supported by the comparison of torque values generated during the BST with those reported during another test of trunk strength (Thorstensson & Arvidson, 1982). The construct validity of the test was supported by its ability to differentiate subjects according to lumbar spinal mobility and according to history of low back pain. The test was concluded to be reliable and suitable for clinical use in testing persons recovering from low back problems.

Conclusions

The results of this study warrant the following conclusions:

1. This testing protocol for isometric strength of flattening of the lumbar curve during posterior pelvic tilt produces stable same-day, same-tester trials for individuals, which differentiate among subjects. It appears to be reliable in the day-to-day and intertester studies.
2. The amount of torque generated by this protocol compares appropriately with that produced during a test of isometric strength of spinal flexion which involved the thoracic spine.
3. Subjects' age, height, or weight, and apparatus factors do not systematically determine performance on the test.

Recommendations

Based on the results of this study, the following recommendations are proposed:

1. The test is recommended for clinical use in monitoring recovery of persons with low back injuries and for research use in identifying predictive factors for low back injury.

2. Persons should be screened for cardiovascular conditions which may be affected by maximum isometric strength efforts. Avoidance of the Valsalva maneuver by careful training in proper breathing techniques is necessary.

3. Development of testing equipment which can expedite further testing of this aspect of back strength is warranted.

Appendix A. Informed Consent

The test for isometric strength of the low back is a reasonably safe test. The procedure involves identifying bones of the spine, an interview relating any history of low back trouble, and bending. The test involves the creation of tension in the muscles of the abdomen, back, hips, and legs, while braced in a standing position. The research involves measuring the amount of isometric tension developed by the low back.

There exists the possibility of certain changes occurring during the testing. Exertion of maximum isometric strength of the muscles of the abdomen, back, hips, and legs can produce muscle fatigue and muscle spasm. Abnormal blood pressure or heart rate response may occur. If any condition of the abdomen, back, hips, or legs or of the circulatory system such as high blood pressure is presently under treatment by a physician, please consult with your physician if you have any concerns about the demands of the test.

Benefits of the test include learning how to create isometric tension in the low back. If you decline to participate, the information will be made available to you if desired.

Participants are free to ask questions concerning all aspects of this test at any time.

Participation in the test is voluntary. The participant is free to withdraw consent and discontinue participation at any time. Should the participant experience pain during the test, the participant should inform the tester and may wish to withdraw from the test.

"In the event physical injury results from biomedical or behavioral research, the human subject should individually seek appropriate medical treatment and shall be entitled to reimbursement or compensation consistent with the self insurance program for Comprehensive General Liability established by the Department of Administration under authority of MCA Title 2, Chapter 9 or by satisfaction of the claim or judgement by the means provided by MCA, Section 2-9-315. In the event of a claim for such physical injury further information may be obtained from the University Legal Counsel."

I have read the preceding and certify that I am physically fit for the test of isometric strength of the low back. I fully know, understand, and appreciate the risks inherent in this test.

I agree to hold Community Hospital harmless for any injury I may incur as a result of participation in this study.

(Signature)

(age)

(date)

(Witness)

Appendix B. Standardization of Position Angle

In order to standardize the angle of the lever arm which is placed at L4L5 with the fulcrum at the greater trochanter, the Position Angle channel of the Dual Channel Recorder of the Cybex II will be used.

1. Balance the arm, with accessories described in the Testing Procedure section, in a vertical position, with the torque at 60°/sec to identify the position of the stylus when the lever arm is vertical.
2. Place the torque at 0°/sec.
3. Test the Position Angle channel calibration.
4. Choose the 150° Position Angle degree scale.
5. Adjust the stylus so that it is at a placement on the fourth major division line above the zero test calibration line, using the goniometer gear dial. This will be considered the "Standard Position" of the stylus.
6. Identify whether the lever arm will be pressed clockwise (CW) or counterclockwise (CCW) by the isometric force of the Maximum Voluntary Contraction (MVC). When the Cybex is positioned on the right of the subject, this will be CW. Set the Input Direction to CW.
7. Place the subject in position with the greater trochanter (GT) at the fulcrum of the lever arm, in the testing position.
8. Adjust the length of the lever arm to be the distance from the GT to L4L5 of the subject's back. Set the torque at 60°/sec and move the lever arm so that the bar presses against the lower back at L4L5. Lock the isometric position by setting the torque at 0°/sec.
9. The Position Angle stylus on the Dual Channel Recorder will be deflected away from the Standard Position (obtained when the lever arm is vertical, i.e., at the fourth major division on the scale). This deflection will be the angle of the lever arm away from the vertical (see Figure 3). Each subject will have a particular deflection angle established during the first test which will be used for all subsequent tests and which will standardize the test position for each subject.

Appendix C. Standardized Instructions to Subjects

For the Test of Maximum Isometric Strength of Flattening of the Lumbar Curve During Posterior Pelvic Tilt: Back Strength Test (BST)

[Instructions were given by the tester to the subject, who was standing in natural posture.]

1. This is a test of the strength of the low back. The strength that is being tested is the ability of the muscles of the back, legs, abdomen, and hips to force the low back backwards.
2. During this test, the hollow of the low back becomes flattened. The front of the hips tilts upward. The back of the hips rocks down and back.
3. I will demonstrate the motion with my hands on my hips [hands placed on the anterior- and posterior-superior iliac spines] so you can see the rocking of the pelvis backwards.
4. Try the motion with your hands on your hips. I will place my hand on the small of your low back to show you how it flattens. Try it in a relaxed way until you can do it three times in a row.
5. Your chest will be held up and stable [demonstrate the thorax held up and stable as pelvis tilts]. You will be required to keep your back upright. Your hips will stay against the lower dowlings. Your feet will need to stay flat on the floor. If the form is not usable, the trial will be repeated.
6. During the test, the strength of this motion will be tested. We will test how much force you can exert or put against the bar at the small of your back. This is an "isometric" test. This means you will not be able to move the bar but will put pressure on the bar without moving it. Put your maximum effort into each trial. Do not hold your breath.
7. Remember, if you experience pain or wish for any reason to stop the test, let me know immediately. The test is completely voluntary and you are welcome to ask any questions or to stop at any time.
8. Remember to put your maximum effort into each trial. There will be a 60-second rest between trials.

[The subject was then placed in the test position.]

Appendix D. Retest Protocol

[Instructions given by the author to the physical therapists being trained in the administration of the Back Strength Test (BST)]

1. Duplicate the spinal curve from the tracing with the architect's flexible ruler. Transfer the spinal sites to the flexible ruler with a pencil.
2. Note the recorded distance from the hairline to C7. Situate the flexible ruler with C7 at that point on the subject's spine. Transfer the spinal sites to the back with a water-soluble pen. The sites include C7, T6, L4L5, 10 cm above L5S1, and 5 cm below L5S1.
3. Using the short input adapter and the shoulder testing accessory, adjust the shoulder testing accessory so that the long arm is vertical. Place the Cybex so that the face is away from the chair.
4. Set the Input Direction to CW and the Position Angle degree scale to 150°. The torque setting will be at 30 ft-lb [40.7 N-m] and Damping at 2.
5. While the testing arm is vertical, adjust the stylus so that it is at a placement on the fourth major division line above the zero test calibration line, using the goniometer gear dial. This will be considered the "Standard Position" of the stylus.
6. Turn the testing arm so that it duplicates the deflection angle on the subject's record. Adjust the height of the Cybex so that it duplicates the height on the testing record.
7. Adjust the dowel braces with the subject standing with heels 3-4 inches from the back board. The top dowel should be behind the thorax at a level of T6, as marked earlier, and the bottom brace should be behind the mark at 5 cm below L5S1.
8. Position the back board so that the subject can be comfortably aligned, with the testing bar behind the low back and with the thorax and pelvis braced on the dowels. The length of the shoulder testing accessory will be placed at the length used in the first test.
9. Instruct the subject according to the Standardized Instructions to Subjects in Appendix C.
10. Explain to the subject that during the first three trials, he will be observing the pen as it records the increasing pressure he is applying to the bar behind the low back. During the fourth and

fifth trials, he will not be able to watch the pen, but will need to rely on his knowledge of how to do the exercise.

11. During each trial, the tester must observe that the subject's shoulders are not pulling away from the thoracic dowel brace and that the heels are remaining flat on the floor. Any trials that do not use the necessary form will not be included in the trials but will be substituted with a later trial using the proper form. The replacement trial will involve the same procedure as the one it replaces (either watching the stylus or not, as appropriate).
12. Place the subject in the test position. Support the upper body with a belt around the chest and arms at a level of T6 (see Figure 2). With the feet shoulder-width apart and 3-4 inches away from the back board, place a belt around the front of the shins, just below the knees.
13. Between trials, relieve the torque in the Cybex, with the subject in the test position but relaxed, by setting the torque briefly to 60° per second, then returning the torque to 0° per second.

Appendix E

Table E-1. Pilot Study Individual Data: Maximum Isometric Torque Produced in Ten Trials ($N = 4$).

Subject	Trial										<u>M</u>	<u>SD</u>
	1	2	3	4	5	6	7	8	9	10		
A	7 ^a	9	10	11	12	10	13	12	14	13	11.1	2.13
B	16	13	15	14	14	15	15	17	16	15	15.0	1.15
C	18	15	15	22	18	15	17	9	14	19	16.2	3.49
D	4	4	4	8	9	3	1	2	4	3	4.2	2.49
<u>M</u>	11.3	10.3	11.0	13.8	13.3	10.8	11.5	10.0	12.0	12.5		
<u>SD</u>	6.80	4.86	5.23	6.02	3.77	5.68	7.19	6.27	5.42	6.81		

^aft-lb.

Table E-2. Main Back Strength Test Study (Same-Day, Same-Tester Study) Individual Data (N = 30, Scores in ft-lb).

Sub- ject	Trial					M of trials			SD of trials 1-5	Sub- ject	Trial					M of trials			SD of trials 1-5
	1	2	3	4	5	1-3	4-5	1-5			1	2	3	4	5	1-3	4-5	1-5	
1	15	17	21	15	16	17.7	15.5	16.8	2.49	16	14	15	15	15	14	14.7	14.5	14.6	0.55
2	20	21	20	22	23	20.3	22.5	21.2	1.30	17	9	5	7	7	6	7.0	6.5	6.8	1.48
3	4	4	5	9	8	4.3	8.5	6.0	2.35	18	3	3	3	4	1	3.0	2.5	2.8	1.10
4	8	9	8	9	10	8.3	9.5	8.8	0.84	19	19	23	24	24	26	22.0	25.0	23.2	2.59
5	18	20	23	23	21	20.3	22.0	21.0	2.12	20	4	5	7	1	1	5.3	1.0	3.6	2.61
6	9	10	11	11	14	10.0	12.5	11.0	1.87	21	8	9	9	8	9	8.7	8.5	8.6	0.55
7	19	17	17	18	17	17.7	17.5	17.6	0.89	22	4	3	4	4	4	3.7	4.0	3.8	0.45
8	13	15	15	17	17	14.3	17.0	15.4	1.67	23	9	9	11	11	12	9.7	11.5	10.4	1.34
9	16	11	14	17	18	13.7	17.5	15.2	2.77	24	6	3	5	4	6	4.6	5.0	4.8	1.30
10	10	10	7	7	9	9.0	8.0	8.6	1.52	25	9	14	14	14	13	12.3	11.5	12.8	2.17
11	13	13	12	11	13	12.7	12.0	12.4	0.89	26	7	5	5	7	7	5.7	7.0	6.2	1.10
12	8	11	9	12	11	9.3	11.4	10.2	1.64	27	8	7	9	9	9	8.0	9.0	8.4	0.89
13	14	15	18	19	13	15.7	16.0	15.8	2.59	28	20	16	15	14	12	17.0	13.0	15.4	2.97
14	16	18	16	18	19	16.7	18.5	17.4	1.34	29	14	17	15	14	14	15.3	14.0	14.8	1.30
15	19	16	16	15	13	17.0	14.0	15.8	2.17	30	5	5	5	4	6	5.0	5.0	5.0	0.71

Table E-3. Day-to-Day Reliability Study Individual Data (N = 4).

Trial	Subject							
	A		B		C		D	
	Day		Day		Day		Day	
	1	2	1	2	1	2	1	2
1	20 ^a	14	8	9	7	4	9	18
2	16	13	7	10	5	4	14	17
3	15	12	9	9	5	4	14	15
4	14	15	9	11	7	5	14	19
5	10	15	9	9	7	5	13	15

^aft-lb.

Table E-4. Intertester Reliability Study Individual Scores.

Tester	Trial	Subject				
		A	B	C	D	E
1	1	25 ^a	14	11	2	9
	2	27	9	12	3	11
	3	24	12	12	3	13
	4	22	12	11	4	12
	5	25	13	14	3	12
2	1	19	8			
	2	21	14			
	3	23	17			
	4	17	17			
	5	15	17			
3	1	22	16	13	4	15
	2	25	15	14	5	13
	3	23	16	14	5	14
	4	28	16	16	6	15
	5	27	18	16	4	13
4	1			13	3	13
	2			12	4	12
	3			13	5	13
	4			14	4	13
	5			11	5	14

^aft-lb.

References

- Adamovich, D. R. (1984). The heart. East Moriches, NY: Sports Medicine Books.
- Adams, M. A., Hutton, W. C., & Stott, J. R. (1980). The resistance to flexion of the lumbar intervertebral joint. Spine, 5, 245-253.
- Addison, R., & Schultz, A. (1980). Trunk strengths in patients seeking hospitalization for chronic low-back disorders. Spine, 5, 539-544.
- Biering-Sorensen, F. (1983). A prospective study of low back pain in a general population. II. Location, character, aggravating and relieving factors. Scandinavian Journal of Rehabilitative Medicine, 15, 81-88.
- Biering-Sorensen, F. (1984). Physical measurements as risk indicators for low-back trouble over a one-year period. Spine, 9, 106-119.
- Bolding, J. (1984). Statistics with finesse [Computer program]. Fayetteville, AR: Author (P.O. Box 339).
- Chaffin, D. B., Herrin, G. D., & Keyserling, W. M. (1978). Pre-employment strength testing: An updated position. Journal of Occupational Medicine, 20, 403-408.
- Cybox (a Division of Lumex, Inc.). (1983). Isolated-joint testing exercise: A handbook for using Cybox I® and the UBXT®. Ronkonkoma, NY: Author.
- Davis, P. R., Troup, J. D., & Burnard, J. H. (1965). Movements of the thoracic and lumbar spine when lifting: A chrono-cyclo-photographic study. Journal of Anatomy (London), 99, 13-26.
- Day, J. W., Smidt, G. L., & Lehmann, T. (1984). Effect of pelvic tilt on standing posture. Physical Therapy, 64, 510-516.
- Ekholm, J., Arborelius, U. P., & Nemeth, G. (1982). The load on the lumbosacral joint and trunk muscle activity during lifting. Ergonomics, 25, 145-161.
- Farfan, H. (1973). Mechanical disorders of the low back. Philadelphia: Lea & Febiger.
- Grieve, D. W. (1974). Dynamic characteristics of man during crouch- and stoop-lifting. In R. C. Nelson & C. A. Morehouse (Eds.), Biomechanics IV (pp. 19-29). Philadelphia: W. B. Saunders.

- Hasue, M., Fujiwara, M., & Kikuchi, S. (1980). A method of quantitative measurements of abdominal and back muscle strength. Spine, 5, 143-148.
- Hemborg, B., Moritz, U., Hamberg, J., Holmstrom, E., Lowing, H., & Akesson, I. (1985). Intra-abdominal pressure and trunk muscle activity during lifting. III. Effect of abdominal muscle training on chronic low-back patients. Scandinavian Journal of Rehabilitative Medicine, 17, 15-24.
- Isaac, S., & Michael, W. B. (1983). Handbook in research and evaluation (2nd ed.). San Diego: EdITS.
- Lindh, M. (1980). Biomechanics of the lumbar spine. In V. H. Frankel & M. Nordin (Eds.). Basic biomechanics of the skeletal system (pp. 255-290). Philadelphia: Lea & Febiger.
- Macrae, I. L., & Wright, V. (1969). Measurement of back movement. Annals of the Rheumatic Diseases, 28, 584-589.
- Marras, W. S., King, A. T., & Joynt, R. L. (1984). Measurement of loads on the lumbar spine under isometric and isokinetic conditions. Spine, 9, 176-187.
- McGill, S. M., & Norman, R. W. (1986). Partitioning of the L4-L5 dynamic moment into disc, ligamentous, and muscular components during lifting. Spine, 11, 666-678.
- McNeill, T., Warwick, D., Andersson, G., & Schultz, A. (1980). Trunk strengths in attempted flexion, extension, and lateral bending in healthy subjects and patients with low back disorders. Spine, 5, 529-538.
- Moran, H. M., Hall, M. A., & Ansell, B. M. (1979). Spinal mobility in the adolescent. Rheumatology and Rehabilitation, 18, 181-185.
- Nachemson, A. L., & Evans, J. H. (1968). Some mechanical properties of the third lumbar interlaminar ligament (ligamentum flavum). Journal of Biomechanics, 1, 211-220.
- Nachemson, A. L., & Lindh, M. (1969). Measurement of abdominal and back muscle strength with and without low back pain. Scandinavian Journal of Rehabilitative Medicine, 1, 1969.
- Nachemson, A. L., Schultz, A. B., & Berkson, M. H. (1979). Mechanical properties of human lumbar spine motion segments. Spine, 4, 1-8.
- Nicolaisen, T., & Jorgensen, K. (1985). Trunk strength, back muscle endurance, and low-back trouble. Scandinavian Journal of Rehabilitative Medicine, 17, 121-127.

- Partridge, M. J., & Walters, C. E. (1959). Participation of the abdominal muscles in various movements of the trunk in man, an electromyographic study. The Physical Therapy Review, 39, 791-800.
- Rodgers, M., & Cavanagh, P. (1984). Glossary of biomechanical terms, concepts, and units. Physical Therapy, 64, 1886-1902.
- Safrit, M. J. (1976). Reliability theory. Washington, DC: American Alliance for Health, Physical Education and Recreation.
- Thorstensson, A., & Arvidson, A. (1982). Trunk muscle strength and low back pain. Scandinavian Journal of Rehabilitative Medicine, 14, 69-75.
- Wells, K. F. (1966). Kinesiology. Philadelphia: W. B. Saunders.
- Wiktorin, C. v. H., & Nordin, M. (1986). Introduction to problem solving in biomechanics. Philadelphia: Lea & Febiger.